TIBIAL KNEE PROSTHESIS

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention is generally related to the field of knee prosthetics and specifically related to the field of tibial trays capable of providing high knee flexion with and without retention of the posterior cruciate ligament.

Description of Related Art

In U.S. Patent Nos. 5,964,808 (the '808 patent) and 6,013,103 (the '103 patent) which are hereby incorporated herein by reference in their entirety, the assignee of the present patent application (Wright Medical Technology, Inc., of Arlington, TN) introduced a knee prosthetic capable of better imitating the complex biomechanics and kinematics of the normal human knee. The knee prosthetic described in the '808 and '103 patents has been, and continues to be, successful, especially at facilitating movement within the normal ranges of knee flexion.

Various scientific publications recognize that the kinematics of a normal, uninjured knee when subject to deep or high knee flexion can become very complex. See, e.g., Bellemans, et al., Fluoroscopic Analysis of the Kinematics of Deep Flexion in Total Knee Arthroscopy, J. Bone Joint Surgery [Br] 84-B:50-3 (2002). Deep knee flexion, as used herein and in the prior art, is the same as high knee flexion and refers to relative movement of the femur with respect to the tibia to an angle of about 90° or greater. Such complex knee kinematics can be difficult to replicate using conventional knee prosthetics which are primarily intended to address more normal ranges of knee flexion.

Another issue associated with the implantation of knee prosthetics is that in some instances a surgeon may elect to retain the posterior cruciate ligament (PCL) of the knee when implanting tibial and femoral components of the knee prosthesis. Generally, it is believed by some that sparing the PCL facilitates a return to normal knee kinematics. Several publications have examined the effects of such PCL-sparing surgeries on knee

kinematics, and in particular, the effects of PCL-sparing on knee kinematics in deep or high flexion. See, e.g., Most, et al., Femoral Rollback After Cruciate-Retaining and Stabilizing Total Knee Arthroplasty, Clinical Ortho. & Related Research, No. 410, pp 101-113 (2003); Bertin, et al., In vivo Determination of Posterior Femoral Rollback for Subjects Having a NexGen Posterior Cruciate-Retaining Total Knee Arthroplasty, 17 J. of Arthroplasty 1040-1048 (2002); Guoan et al., Cruciate-Retaining and Cruciate-Substituting Total Knee Arthroplasty, 16 J. of Arthroplasty 150-156 (Supp. 2001); Sorger, et al., The Posterior Cruciate Ligament in Total Knee Arthroplasty, 12 J. of Arthroplasty 869-879 (1997); Stiehl, et al., Fluoroscopic Analysis of Kinematics After Posterior Cruciate-Retaining Knee Arthroplasty, J. Bone Joint Surgery [Br] 77-B: 884-889 (1995); Mahoney, et al., Posterior Cruciate Function Following Total Knee Arthroplasty, 9 J. of Arthroplasty 569-578 (1994). Regardless of the efficacy of sparing the PCL, its retention often increases the complexity of knee kinematics throughout the range of knee flexion. In particular, PCL retention can result in combined shifting and pivoting of the femur with respect to the tibia due to its exertion of a laterally directed force on the femur.

Different prosthetic devices have been developed to address the various issues associated with deep knee flexion. In one example, there are knee prosthetics in which the tibial tray rotates with respect to the tibia, by being mounted for rotation on its tibial base. In another example, there are knee prosthetics in which the tibial tray translates (or slides) with respect to the tibia, by being mounted for translation (sliding) on its tibial base. There are also knee prosthetics in which the tibial tray both rotates and translates with respect to the tibia, by being mounted for rotation and translation on its tibial base. Although these prosthetic devices provide one option to facilitate high knee flexion, they are relatively complex due to the required relative movement of the components with respect to their supporting bones.

Prosthetic devices have also been developed having a high anterior lip that allows for resection of the PCL, or protects the PCL in a PCL-sparing surgery. However, additional options for PCL sparing, especially prosthetics that also account for deep knee flexion, are still desirable.

Therefore, it would be advantageous to have a knee prosthesis that allows for more normal kinematic motion at higher or deeper flexion angles. In addition, it would be advantageous if such a prosthetic provided for retention of the PCL as is preferred by many surgeons.

OBJECTS OF THE INVENTION

It is an object of the present invention is to provide a tibial knee prosthesis that allows for complex, combined motion of the femur with respect to the tibia which is believed to be more consistent with the natural motion of knees in deep flexion and allows for retention of the PCL in knee replacement surgeries.

It is a further object of the present invention is to provide a tibial knee prosthesis that allows for posterior and lateral motion during deep knee flexion, or in PCL-spared knees.

These and other objects of the invention are achieved by a tibial knee prosthesis having a medial concavity with a generally triangular shaped area bounded by an area of conformity. An anterior peak of the triangular shaped area facilitates effective low knee flexion activity wherein the medial femoral condyle primarily rotates with respect to the tibia. A wider posterior base of the generally triangular shape facilitates freer motion in moderate to deep flexion, including laterally directed motion from the PCL and posterior sliding with respect to the tibia.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING(S)

Having thus described the invention in general terms, reference will now be made to the accompanying drawings, which are not necessarily drawn to scale, and wherein:

Figure 1 is an exploded perspective view of a prior art right knee prosthesis;

Figure 2 is a top plan view of the tibial component of the prior art knee prosthesis of Figure 1;

Figure 3 is a sectional view substantially as taken on line 3--3 of Figure 2, with portions thereof omitted for clarity;

Figure 4 is a sectional view substantially as taken on line 4--4 of Figure 3, with portions thereof omitted for clarity;

Figure 5 is a sectional view substantially as taken on line 5--5 of Figure 3, with portions thereof omitted for clarity;

Figure 6 is a somewhat diagrammatic medial sagittal sectional view of the prior art knee prosthesis of Figure 1, shown implanted in a knee joint with the knee joint substantially fully extended;

Figure 7 is a somewhat diagrammatic lateral sagittal sectional view of the prior art knee prosthesis of Figure 1, shown implanted in a knee joint with the knee joint substantially fully extended;

Figure 8 is similar to Figure 6 but shows the knee joint partially flexed;

Figure 9 is similar to Figure 7 but shows the knee joint partially flexed;

Figure 10 is similar to Figure 6 but shows the knee joint flexed substantially 90°;

Figure 11 is similar to Figure 7 but shows the knee joint flexed substantially 90°;

Figure 12A depicts a general and schematic representation of the kinematics of the prior art medial pivot knee of Figures 1-11;

Figure 12B depicts a view along line 12B--12B of Figure 12A;

Figure 13A is a sectional view of a medial concavity of a tibial tray of one embodiment of the present invention supporting a femur of a knee in deep flexion;

Figure 13B is a plan view of the tibial tray of Figure 13A supporting the femur;

Figure 14 is a perspective view of the tibial tray of Figure 13A;

Figure 15 is a schematic view of kinematics of the femur on the tibial tray of Figure 13A;

Figure 16 is a sectional view of the medial concavity of the tibial tray shown in Figure 13A;

Figure 17 is a sectional view of the lateral concavity of the tibial tray shown in Figure 13A; and

Figure 18 is the knee of Figure 13A in normal flexion.

DETAILED DESCRIPTION OF THE INVENTION

The present invention now will be described more fully hereinafter with reference to the accompanying drawings, in which some, but not all embodiments of the invention

are shown. Indeed, this invention may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will satisfy applicable legal requirements. Like numbers refer to like elements throughout.

The invention is an improvement to the prior art medial pivot knee described in commonly assigned U.S. Patents Nos. 5,964,808 and 6,013,103. The knee prosthetics taught by these patents will now be briefly described herein for context with respect to the exemplary preferred embodiment.

The knee prosthesis **3.11** is designed to replace at least a portion of a knee joint **13** between a distal end **17** of a femur **15** and a proximal end **21** of a tibia **19**, as shown in Figures 6-11. The femoral component **3.23** includes, in general, a medial condylar portion **3.27**, a lateral condylar portion **3.29**, and a patellar flange portion **3.31**, as shown in Figure 1. Reference should be made to the '103 patent for a complete and thorough understanding of the construction and function of the femoral component **3.23**. It is possible, however, for the invention to be used with other femoral implants, including uni-compartmental femoral implants, or even with the patient's natural femur.

A tibial component **3.25** of the knee prosthesis **3.11** includes a base or tray member **3.43** for being secured to the proximal end **21** of the tibia **19**, and an articular bearing, insert or superstructure member **3.45** for being fixedly mounted on the base member **3.43**, as shown in Figure 2.

The base member **3.43** preferably includes a head portion **3.46** and attachment aids **3.59** for helping to secure the head portion **3.46** to the proximal end **21** of the tibia **19**, as shown in Figures 3-5. The attachment aids **3.59** may include one or more pegs, fins, screws, surface treatments, etc., on the lower surface of the head portion **3.46** as is apparent to those skilled in the art. In addition, the upper surface of the head portion **3.46** may include articular bearing attachment aids (not shown) for helping to fixedly secure the articular bearing member **3.45** to the base member **3.43**. Such articular bearing attachment aids may include one or more undercut flanges extending upward from the upper surface of the head portion **3.46** for co-acting with co-acting grooves in the lower surface of the articular bearing **3.45** such as the attachment aids disclosed at column 2, lines 46-52 of the '808 patent.

The base or tibial tray member **3.43** can be constructed in various manners and out of various materials. Thus, for example, the base member **3.43** can be machined or molded from one or more material components.

Also as described in the '808 patent, the articular bearing member **3.45** has an upper or proximal surface **3.67** with a medial concavity **3.79** and a lateral concavity **3.81** for pivotally receiving and co-acting with the face surfaces of the respective medial and lateral condylar portions **3.27**, **3.29** of the femoral component **3.23**, as shown in Figure 1. The articular bearing member **3.45** also has a lower or distal surface for being fixedly secured to the upper surface of the head portion **3.46** of the base member **3.43**, as shown in Figures 3-5.

The medial concavity **3.79** has a face surface **3.83** for articulatingly receiving a portion of the face surface of the medial condylar portion **3.27** of the femoral component **3.23**. The face surface **3.83** is preferably defined by a precise proximal sagittal curvature formed by the radius **R6** shown in Figure 4. In addition, a precise proximal coronal curvature is formed by the radius **R7** shown in Figure 3. The radius **R6** is preferably the same size as the radius **R7** so that the face surface **3.83** forms a semispherical shape.

In addition, the radii **R6**, **R7** are preferably substantially congruent with or approximately the same size as the radii of the sagittal and coronal curvature of the medial femoral condyle **3.27** with appropriate clearances. In this manner, there can be substantially complete surface-to-surface contact between the face surface of the medial condylar portion **3.27** of the femoral component **3.23** and the face surface **3.83** of the medial concavity **3.79** of the tibial articular bearing member **3.45** throughout a significant portion of the range of flexion of the knee joint **13**. This range of flexion, for example, may be between about full extension of the knee joint **13** (as shown in Figure 6) and approximately 60° of flexion of the knee joint **13** (as shown in Figure 8).

The lateral concavity **3.81** has a face surface **3.84** for articulatingly receiving a portion of the face surface of the lateral condylar portion **3.29** of the femoral component **3.23**. The face surface **3.84** is preferably defined by a precise proximal coronal curvature formed by the radius **R8** shown in Figure 3, a precise anterior sagittal curvature formed by the radius **R9** (as shown in Figure 5) and a precise posterior sagittal curvature formed by the radius **R10** (as also shown in Figure 5).

The radii **R8**, **R9**, **R10** are preferably substantially congruent with, or approximately the same size as, the radii as the lateral condyle with appropriate clearances. This substantial congruity promotes a substantial surface-to-surface contact between the face surface of the lateral condylar portion **3.29** of the femoral component **3.23** and the anterior end of the face surface **3.84** of the lateral concavity **3.81** of the tibial articular bearing member **3.45** during full extension of the knee joint **13**, as shown in Figure 7. There is preferably also substantial surface-to-surface contact between the face surface of the lateral condylar portion **3.29** of the femoral component **3.23** and the posterior end of the face surface **3.84** of the lateral concavity **3.81** of the tibial articular bearing member **3.45** during partial or greater extension of the knee joint **13**, as shown in Figure 9.

The lateral concavity **3.81** is preferably curved in a bean-like shape when viewed in plan (as shown in Figure 2) so that during flexion of the knee joint **13**, the femur **15** can rotate about a point **391** which is the most distal point within the medial concavity **3.79**. As shown in Figure 12B, the point **391** is at an intersection of a vertical line **L** extending in the proximal-distal direction and the surface defining the medial concavity. As is shown schematically in Figure 12A, a medial-lateral axis extending through both the medial and lateral condyles represented by line **390** rotates about the point **391**. This causes the lateral condylar portion of the femur (which is represented by the lateral end of the line **390**) to swing about an arc **392** within the lateral concavity **3.81**.

As previously mentioned, during deep flexion situations, the femur tends to posteriorly translate and rotate. This posterior translation and rotation can probably be equated (in terms of mechanics as opposed to directions) with the "combined spin and roll" motion previously recognized in studies of knee motion. See Blaha, et al., <u>Kinematics of the Human Knee Using an Open Chain Cadaver Model</u>, Clinical Ortho. & Related Research, No. 410, pp. 25-34 (2003) which is incorporated herein by reference.

By taking into account this better understanding of the biomechanics of the human knee, as understood by the current inventors, the present invention modifies the tibial prosthesis according to the '808 patent. These modifications allow the tibial prosthesis of the invention to better handle deep knee flex situations without the femur dislocating out of the tibial tray and accommodate those situations in which the PCL is

retained. Generally, this is accomplished by modifying the medial concavity to have multiple conforming portions that can provide surface-to-surface contact between the medial femoral condyle and the medial concavity. These multiple conforming portions allow for sliding, rotation and other compound movements that are more consistent with the actual motion of a normal knee in deep or high flexion.

For example, as shown in Figure 14, in one embodiment the present invention includes a tibial prosthetic or tray **443** that is an articular bearing member and includes a medial concavity **479** and a lateral concavity **481**. The medial concavity **479** is shaped to receive and interact during knee articulation with a medial condyle, while the lateral concavity **481** is shaped to receive and interact with a lateral condyle. For instance, the concavities may receive and interact with the medial condyle **3.27** and the lateral condyle **3.29** of the femoral component **3.23** illustrated in Figure 1. However, it should be noted that the tibial tray **443** is not limited to receiving the condyles of any particular type of femoral prosthesis and in fact could also interact with the condyles of a normal knee.

As is shown best in Figure 14, the concavities **479, 481** are defined by raised and curved bearing surfaces upon which the femoral condyles **3.27, 3.29** can roll, slide, and pivot, or otherwise move in all degrees of freedom. However, it is strongly desirable that the condyles remain in contact (i.e., "conformity") with the concavities throughout the entire range of knee flexion, including deep flexion where knee dislocation in a normal knee is most likely to occur.

It should also be noted that although the tibial tray **443** in the illustrated embodiment is shown as being constructed of a unitary piece of material, it is also possible for the tibial tray to include multiple components. For instance, the tibial tray could include two separate trays, wherein each one of the trays defines a respective one of the concavities **479, 481**. Tibial prostheses with two separate trays are typically known as unicompartmental knees as described, for example, in commonly assigned PCT publication WO 03/045256, which is hereby incorporated herein by reference. Also, the material used to construct the tibial tray **443** is preferably an ultra-high molecular weight polyethylene (UHMPE), but it could also be constructed of various metals, polymers, and other materials, singly or in combination and still fall within the purview of the present invention.

For the purposes of the following discussion the term "anterior" is intended to mean pivot point **491** and all points anterior of the medial-lateral line AP-AP passing therethrough, as shown in Figure 15.

As shown in Figure 15, the medial concavity **479** of the tibial tray **443** includes a first portion **400** and a second portion **401** that engage the medial femoral condyle **3.27** during normal, and high, knee flexion, respectively. The first and second portions **400**, **401** are most easily described in reference to modifications performed on the previously described, and preferably hemispherical, medial concavity **3.79** illustrated in the '808 patent. Generally, the first portion **400** is in the anterior portion of the medial concavity and interacts with the medial femoral condyle **3.27** during normal flexion. The second portion **401** is in the posterior area of medial concavity **479** of the tibial tray **443** and interacts with the medial femoral condyle **3.27** during high flexion and/or due to motion imparted on the femur by the PCL.

In the embodiment illustrated in Figures 14 and 16, the aforementioned first portion **400** is defined as any portion of the medial concavity extending anteriorly from an imaginary line AP-AP passing medially-laterally through the pivot-only point **491**. Generally, the first portion **400** of the tibial tray **443** corresponds, therefore, to the portion of the medial concavity of the tibial tray of the '808 patent which falls on and is anterior to pivot point **491**.

The second portion **401** is generally defined as any portion of the medial concavity **479** other than the first portion. Specifically, this includes the portion of the medial concavity posterior to, but not including, the imaginary line AP-AP passing medially-laterally through the pivot-only point **491**, as shown in Figure 15. Despite the above-described preferred embodiment, it should be noted that the first and second portions could at least partially overlap, especially in the lateral concavity **481** during the application of external (e.g., muscle) forces where the posterior motion of the femur during high knee flexion is not as definite.

Even more specifically, the second portion is formed as follows. First, the posterior portion of the prior art medial concavity **3.79** is extended posteriorly (see Figure 16). This is achieved by moving the pivot point **491**, which as previously mentioned is also the lowest point in the medial concavity **3.79** of the '808 patent, posteriorly along a

line perpendicular to the medial-lateral line AP-AP to point **491′**. As a result, medial concavity now has a linear flat portion **492**, as shown in Figures 14 and 16.

The entire posterior movement of pivot point **491** is foreseen as preferably being from 3 mm to 7 mm, or more preferably from 3 mm to 5 mm, or from 4 mm to 5 mm depending upon the size of the patient's knee. The various raised bearing surfaces surrounding the entire posterior portion of the medial concavity are also moved further posteriorly by approximately the same amount from point **495** where they would be in the medial concavity **3.79** of the '808 patent to point **495′**, as shown in Figure 16.

The second portion of the medial concavity is also swept laterally at an angle. In the preferred embodiment, this is achieved by sweeping linear flat portion **492** at an arc of, for example, 30° in a lateral direction at a radius equal to the amount by which pivot point **491** was extended posteriorly. Of course other ranges of sweep could also be used such as 15°, 20°, 40°, 45°, or more, depending upon the amount of desired lateral movement. As shown in Figure 15, this results in medial concavity **479** having a conforming area **510** whose boundary is not well defined (as will be described later) and containing a generally triangular shaped flat portion **490** of the illustrated embodiment. To account for the movement of the medial femoral condyle **3.27** into the medial portions of the generally triangular shaped flat portion **490**, the original raised lateral bearing surface walls of the medial concavity **479** are moved laterally by an amount equal to the normal lateral motion of a medial condyle in high flexion while still taking into account the secondary design factors previously mentioned.

In the illustrated embodiment, the triangular shaped flat portion **490** preferably includes a peak and base portions which generally encompass or include portions the first and second portions, **400**, **401**, respectively. Referring again to Figure 15, the peak portion extends generally in an anterior direction while the base includes the posterior two corners of the generally triangular shaped portion. One of the corners of the base extends laterally somewhat so as to allow lateral rotation of the medial femoral condyle **3.27** resulting from sparing of the PCL or deep flexion of the knee.

The lateral concavity **481** includes its own peripheral boundary **511** (as shown by a broken line in Figure 15) which defines a modified portion of the lateral concavity **3.81** of the '808 patent. Generally, the peripheral boundary **511** is defined so as to ensure that

there is no dislocation of the lateral condyle **3.29** out of the lateral concavity **481** due to the increased motion caused by the above-described modifications to the medial concavity **479**, as shown by the peripheral boundary **510**. Preferably, the area bounded by the peripheral boundary **511** is relatively flat to allow expanded sliding or rolling motion until the lateral condyle extends onto the upwardly curved surfaces surrounding the peripheral boundary, as shown in Figure 17. Notably, it is preferred if both the medial and lateral condyles **3.27**, **3.29** encounter the upwardly curved surfaces surrounding the boundaries **510**, **511** in roughly the same position so that all of the restraint against dislocation is not provided by only one of the concavities **479**, **481**.

Without being wed to theory, it is believed that the above-described improvements to the tibial tray **443** result in relative tibial-femoral motion that is more consistent with normal knee kinematics throughout a full range of flexion than most conventional knee prosthetics without the complexity of a moving tibial tray. As shown in Figure 13A, during deep flexion of the knee joint **13**, the femur **15** is bent backwards greater than approximately 120° (angle **Q**) from tibia **19**. As a result of this flexion, the entire femur **15** moves (translates) posteriorly in the direction of arrow **T** as allowed by the relatively flat surface within the peripheral boundary **510**. This movement is symbolized by a resulting gap **G** between femoral condyles **3.27**, **3.29** and an anterior lip **326** of the tibial tray **443**.

This posterior translation, however, is not uniform in the medial-lateral direction due to rotation of the femur **15** with respect to the tibia **19**, as shown in Figure 13B. In particular, the gap **G** between the femoral condyles **3.27**, **3.29** and the anterior lip **326** varies at a medial side **G1**, a middle portion **G2**, and a lateral side **G3**. In particular, the gap increases progressively from **G1** to **G2** and then **G3** in the illustrated embodiment. This progressive increase in the gap **G** in the lateral direction is facilitated by the posteriorly directed expansion of the peripheral boundary **510** of the medial concavity **479** of the tibial tray **443** of the present invention.

The improvements of the tibial tray **445** of the present invention also allow for differences in motion caused by retention of the PCL. For instance, the PCL (represented schematically by a line **700** in Figure 13B) is allowed by the present invention to further contribute to rotation of the femur **15** with respect to the tibia **19**, as it would in a normal

knee. The PCL **700** is connected to the posterior middle of the tibia **19** at one end, extends through an inter-condylar notch **20** of the distal femur **17**, and then connects to the distal femur at its other end.

It should be noted that the PCL's connection to the distal femur **17** is offset somewhat in the medial direction due to its connection to the lateral side of the medial femoral condyle **3.29**. Accordingly, this offset connection creates a natural tendency on the femur **15** as a whole to rotate in the lateral direction with respect to the tibia **19**, even when the knee is not in flexion or deep flexion. The resulting lateral rotation of the PCL-sparing surgery is taken into account by the tibial tray **443** of the present invention, as described below.

Referring to Figure 15, which are indicative of the kinematics of a knee using the tibial tray **443** of the present invention at particular moments in time, the result of high-flexion and forces from the PCL on the femur **15** is posterior translation and lateral rotation of the femur within the peripheral boundaries **510, 511**. It should be noted that "rotation" of the femur **15** as described with respect to the present invention is not about a single stationary point as it is described with respect to the medial concavity of the tibial tray of the '808 patent. Rather, with the present invention, it is more likely that incremental rotation **R1** of the medial condyle of the femur, as represented by the medial-lateral axis **390**, occurs while the femur translates in directions indicated by arrows **M1** and **M2** (having lengths not necessarily to scale), as is also shown in Figure 15.

Also as a result of the above-described compound motions allowed by the medial concavity **479** of the tibial tray **443** of the present invention, the kinematics of the knee joint **13** change when moving from normal flexion angles to deep or high flexion angles. For instance, when the knee joint **13** is an a normal flexion position, the medial condyle **3.27** only pivots about point **491** which remains stationary and is substantially identical in position to point **491** in the medial concavity **3.79** described in the '808 patent. Therefore, the knee joint **13** mimics medial pivot knee joint summarily described above and in the '808 patent in normal knee flexion. This is shown in Figure 15 by the solid schematic version of femoral axis **390** and its associated solid lateral concavity arc **392**.

When the knee joint **13** is bent towards deep flexion or the PCL acts upon the femur **15** (whether it is in deep flexion or not), the medial condyle **3.27** tends to translate

posteriorly in direction **M1** while simultaneously translating posteriorly and somewhat laterally in direction **M2**. In summation, this simultaneous translation may be represented as one movement in the direction of arrow **M3**. The general limits of the combined movements **M1, M2**, or **M3** define the peripheral boundary **510** of the medial concavity **479**.

The above-described compound motion of the femur **15** on its medial side causes a corresponding compound motion on its lateral side substantially surrounded by lateral peripheral boundary portion **511** contained within lateral concavity **481**. Generally, in the illustrated embodiment of Figure 15, the peripheral boundary **511** of the lateral concavity **481** is larger than peripheral boundary **510** of the medial concavity **479** so as to allow the lateral end of femoral axis **390** to take many angles and positions based upon a single position of the medial femoral condyle **3.27**. For example, various changed positions of the femoral axis based upon a single position of the medial femoral condyle **3.27** are shown by broken lines **390′**, **390″**, and **390‴**.

As previously noted, peripheral boundaries **510, 511** are not precisely defined or constrained by biomechanics, anatomy, surgical method, or manufacturing method, and therefore may vary or be varied depending upon these and other factors and still fall within the scope of the present invention. Accordingly, the peripheral boundaries **510, 511** are shown in the accompanying figures defined by broken lines. In fact, the present invention encompasses modification of the medial concavity **479** to allow a change in the position of the medial femoral condyle **3.27** on the tibial tray **443** when entering higher flexion, and/or retention of the PCL.

Therefore, although the embodiment of the present invention illustrated herein emulates one investigator's determination that deep or high knee flexion results in posterior and lateral movement of portion of the tibia on which the femoral condyles interact, different concepts and factors may also be applied and will still fall within the scope of the present invention. For instance, any tibial tray **445** design would be within the scope of the present invention as long as interaction constraint (conformity) between the medial femoral condyle **3.27** and the medial concavity **479** varies during high flexion.

Having described the structure of the invention, its operation will now be described. The tibial tray **443** is initially implanted into the body using conventionally

known surgical techniques and instruments. Furthermore, because the tibial tray **443** is intended to be used in PCL retaining surgeries, the surgeon may opt to not dissect the PCL during implantation. As mentioned above, the surgeon may implant a range of femoral components, such as the femoral component **3.23** of the '808 patent, or may elect to not implant any femoral component.

During standing and relatively straight-legged activities where the femur is in-line with the tibia, the femoral condyles remain mainly in contact with the first portions **400** of the medial and lateral concavities **479, 481**. Generally, in this mode, the tibial tray **443** of the present invention is operating in a manner similar to the tibial tray **3.43** described above and in the '808 patent.

Upon some normal-range flexion with action of the PCL, the femur **15** pivots about its sagittal axis and the medial condyle **3.27** begins to move posteriorly into the second portion **401** of the medial concavity **479**, posterior of pivot point **491**, as shown in Figure 18. The lateral condyle **3.29** also moves into its respective second portion **401** as it follows the lead of the medial condyle **3.27** and the movement of the femur **15** as a whole. Generally, during this phase of movement, movement of the medial condyle **3.27** comprises sagittal pivoting and posterior translation only.

During deep flexion, or normal flexion but with the PCL acting upon the femur, the medial condyle **3.27** begins to move laterally and posteriorly, as shown in Figures 13A and 13B. The lateral condyle **3.29** moves and rotates even more as it follows the movement of the femur **15** as a whole, as shown schematically by Figure 15. Once relatively deep flexion has been reached, the condyles **3.27, 3.29** are then constrained by the raised bearing surfaces within their respective concavities **479, 481** to prevent dislocation.

The present invention has many advantages. For instance, the use of first and second portions in the medial concavity **479** allows for complex, combined motion of the femur with respect to the tibia which is believed to be more consistent with the natural motion of knees in deep flexion and allows for retention of the PCL in knee replacement surgeries. In particular, the presence of posterior and lateral expansion of the medial concavity **479** as defined by the peripheral boundary **510** allows for posterior and lateral motion during deep knee flexion, or in PCL-spared knees. Further, the preferred

embodiment's generally triangular shape of the peripheral boundary with an anterior peak facilitates the effective low knee flexion activity wherein the medial femoral condyle **3.27** primarily rotates. On the other hand, the wider posterior base of the generally triangular shape facilitates freer motion in moderate to deep flexion, including laterally directed motion from the PCL and posterior sliding.

Many modifications and other embodiments of the inventions set forth herein will come to mind to one skilled in the art to which these inventions pertain having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the inventions are not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.